FabTime Cycle Time Management Newsletter

Volume 11, No. 1 January 2010

Information

Mission: To discuss issues relating to proactive wafer fab cycle time management

Publisher: FabTime Inc. FabTime sells cycle time management software for wafer fab managers. New features in this month include forecast arrivals charts and the ability to shift dates and times to local time zone.

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Welcome

Welcome to Volume 11, Number 1 of the FabTime Cycle Time Management Newsletter! We wish you all a happy and productive 2010. We're starting the new year off with a couple of new software purchase orders, so we're feeling optimistic here at FabTime. And, amazingly (to us, anyway), this is the 99th issue of the newsletter. We're working on a bit of a celebration for the 100th issue, scheduled for publication at the beginning of March. In this issue, we have two community announcements, and one response to a previously introduced subscriber discussion topic. Our FabTime user tip of the month is about using the new Forecast Arrivals Charts to predict future arrivals to a particular tool or step.

In our main article this month we return to a topic first discussed five years ago, the effect of product mix on fab cycle time. Our return to this topic was triggered by a question raised in discussion with a friend: Is it inevitable that cycle time increases as you add technology mix to an existing fab (because you have more dedication, smaller tool groups, tools at higher utilization, more setups, smaller batches, etc.)? In light of this question, we have revised and expanded our previous thoughts on product mix and cycle time, and added some new suggestions for mitigating the negative effects. We welcome your feedback!

Thanks for reading!—Jennifer

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Community News/Announcements

Special ITRS Issue of Future Fab International

Future Fab International recently released a special issue dedicated to the International Technology Roadmap for Semiconductors (ITRS). Members can download the issue from this link: www.future-fab.com/download.asp. There is no charge for membership. Here's a brief introduction to the issue:

"In a year in which each of the ITRS Technology Working Groups (TWGs) completed guideline rewrites, this issue brings you synopses written exclusively for Future Fab readers by all 16 of the TWGs. These executive summaries provide an overview of the work that each TWG is tackling. At the end of each synopsis you'll find a link that takes you back to the ITRS site for the complete article.

The Future Fab ITRS Annual issue begins with an introduction from ITRS Chairman (and Future Fab panel member) Dr. Paolo Gargini, and follows up with articles presenting cutting-edge opinion and research on all ITRS-sponsored initiatives, ranging from ESH issues to factory integration, and from lithography to metrology."

ISMI Manufacturing Week 2010

The International Sematech Manufacturing Initiative recently announced that ISMI Manufacturing Week 2010 will be held from October 31st through November 4th in Austin, TX. Here are some details from the conference announcement and call for papers:

"New this year... ISMI Manufacturing Week is expanding to include ISMI's AEC/APC Symposium as well as the 7th ISMI Symposium on Manufacturing Effectiveness. The AEC/APC Symposium, which for nearly 20 years has led the industry's effort to accelerate the move toward more efficient and more intelligent manufacturing through data-driven and automated decision making, is a natural complement and a welcome addition to the ISMI Manufacturing Week agenda.

Call for Papers

Increased manufacturing productivity—including advanced equipment and process controls—as well as reduced operational costs are absolutely critical for a profitable manufacturing facility. ISMI Manufacturing Week is the semiconductor industry's most important event for exchanging ideas about real-time, cost-saving solutions to help your company be more productive.

Submissions for both symposia will be accepted February 22 - June 25. For more information, visit the ISMI Manufacturing Week website: http://ismi.sematech.org/-ismisymposium."

FabTime welcomes the opportunity to publish community announcements. Send them to newsletter@FabTime.com.

FabTime User Tip of the Month

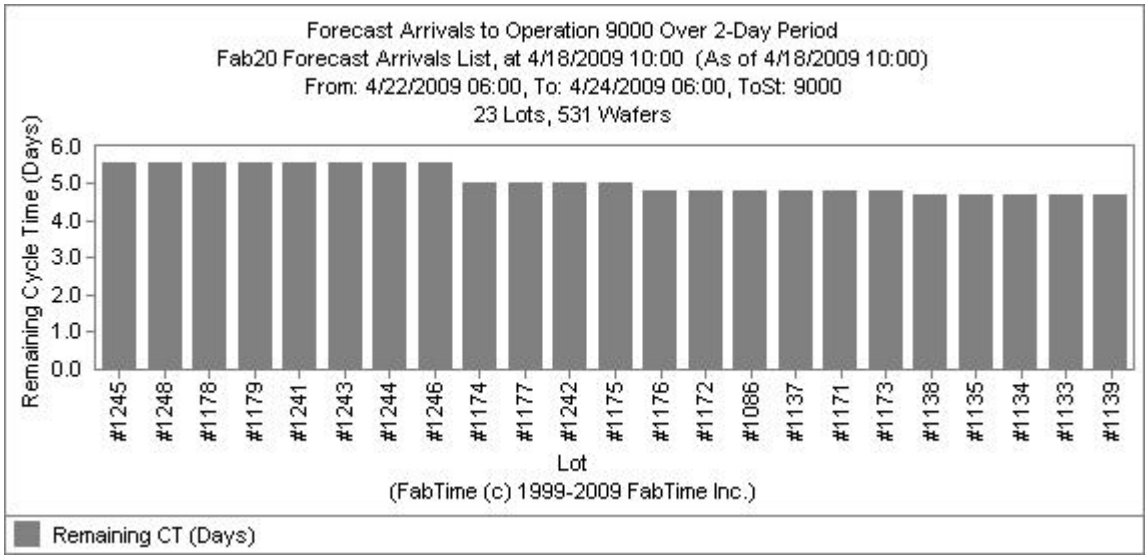
Forecast Future Arrivals to a Tool or Step

FabTime has for quite a while had the capability of forecasting outs from a particular tool or step. This feature was designed to be used to forecast outs from the fab over some future time window. However, it was (and is) possible to use it to forecast the lots that would exit from any step or tool. In response to customer requests, we've created a parallel set of charts that allow users to forecast the arrivals to any step or tool. This arrival-based version of the charts is more useful for managing a particular tool, by giving operators a sense of which lots are likely to arrive in the near future.

To use the Forecast Arrivals charts, expand the Forecast Charts category on the FabTime chart list, and select Forecast Arrivals Trend, Forecast Arrivals Pareto, or Forecast Arrivals Lot List. Enter your desired future time window and enter a value into either the "ToSt:" or "ToTl:" field (one, but not both). Hitting enter will refresh the chart, and bring up either the number of wafers expected to arrive during each period (for the trend and pareto charts) or a list of the specific lots (for the lot list chart). The projections for this chart are based on the planned cycle times by step stored in FabTime. If your site does not have planned cycle time data in FabTime, then nothing will be displayed on the charts. However, as long as FabTime has information about the expected cycle times by step, it can project each lot forward, and predict which lots will arrive during your designated time window. The predictions are based on this static, planned data, and not on any kind of simulation, and hence the accuracy of the charts will be a function of the quality of the planned cycle time data.

Please note that any other filters that you use on the Forecast Arrivals charts (and the Forecast Outs charts) apply to the WIP when at its current operation. The ToSt and ToTl filters are the only ones that apply to the future step. So, for example, if you specify operation 9000 for the to step, and then enter operation 7500 into the "Opn" filter, FabTime will display all of the lots that are currently at operation 7500 that are expected to arrive at operation 9000 during the target window. Similarly, entering "ToolA" into the "Tool" filter for the same example will result in a list of all of the lots that are currently at ToolA, and that are expected to arrive at operation 9000 during the target time window.

If you have any questions about this feature, just use the Feedback form.



Subscriber Discussion Forum

Operator Productivity

Dan Dalpiaz from NPI (Norwich Pharmaceuticals Inc.) wrote in response to last month's subscriber discussion question from Bruce Fan of SMIC: "Operator productivity is a hot topic for all of us. I dream of one day being able to collect enough data regarding particular tasks to determine what operator is most efficient at a particular task and use them as the top of the learning curve. In my business, pharmaceuticals, great efficiencies could be made if we knew what operator was the best at a particular task, then coupling them with others who are better at other tasks. Building the ultimate team! In order for me to get real data each task needs to be determined and tracked from start to finish. Essentially tracking cycle times of smaller tasks which are ultimately all of entire cycle time. As simple as it seems I have not seen this in any business I have worked in. Imagine what it takes to make a gallon of orange juice. Rather than just measuring how long it takes to produce the gallon, if we knew how long it took different places to grow them, to pick, clean, squeeze, pasteurize, and package we could take the fastest of each to teach the slower steps."

FabTime welcomes the opportunity to publish subscriber discussion questions and responses. Simply send your contributions to Jennifer.Robinson@-FabTime.com.

Product Mix and Cycle Time, Revisited

Introduction

Five years ago (in issue 6.01) we wrote about Product Mix and Cycle Time. Recently, in a discussion with a long-time FabTime customer, this question arose: Is it inevitable that cycle time increases as you add technology mix to an existing fab (because you have more dedication, smaller tool groups, tools at higher utilization, more setups, smaller batches, etc.)? We thought, because it's been such a long time since we formally addressed product mix in the newsletter, and since technology mix appears to be ever-increasing in wafer fabs, that it was high time to revisit this topic. This article is based on the previous article from 2005, expanded and revised, and with new references.

When we ask people about factors contributing to cycle time problems in their fabs, a response that we've been hearing with ever-increasing frequency over the past five years is "product mix" (or process mix, or technology mix). This makes sense to us. First of all, mix is increasing in fabs because of the proliferation in the variety of end products in the marketplace. There's ever more pressure to produce more products over shorter timeframes. Second, the longer a fab is in operation, the more likely it is to end up running multiple technologies in the same fab, using the same basic toolset. And many people report that having a high degree of product mix (especially when the products are of different technologies)

tends to make it harder to achieve great cycle time. But why is that, exactly? And is there anything that can be done? In this article, we discuss some of the reasons why having a high degree of product/technology mix may drive up fab cycle times.

There are many different types of high mix fabs represented among our newsletter subscriber base. There are high volume fabs that run a wide range of different products, often using different technologies, scaling products up or down according to customer demand. Then there are lower volume fabs that have short product cycles, and are constantly introducing new products. And of course, let's not forget the production fab that also runs development wafers. For all of these fabs, and others, product mix may be driving up cycle times.

When we talk about product mix in this article, we will consider two different aspects of a product/process mix. The first is the sheer number of different products (especially when they are of different underlying technologies). The second is the rate at which product life cycles change (variation in products). Both number of products and product life cycle changes contribute to variability in fabs. And no matter where you are on the upturn /downturn cycle, variability is still bad for cycle time. In the sections below, we will discuss some specific mix-related issues.

High Mix: Number of Products

Just having many different products in your fab contributes to variability. This is particularly true when you have products that have different underlying technologies (e.g. different wafer size, or different geometries). One of the trickiest cases is when a fab is transitioning from one wafer size to another, or from one fundamental type of technology to another, and running both types of wafers in the interim. This usually requires the dedication of certain tools to one wafer size or technology, while other tools are dedicated to the other wafer size or technology. The result is smaller tool-groups, and even one-of-a-kind tools. We've talked extensively in the newsletter about the detrimental impact of one-of-a-kind tools on cycle time (most recently in Issue 9.01). Our rough estimate is that if an existing fab has to shift to running major process flows on a one-of-a-kind toolset, the cycle time for those flows is likely to double (compared with running on a toolset with redundancy).

Other, day-to-day issues that stem from having a wide range of products in a fab include:

Process Time Variability. If you have many different products in your fab, then you likely run many different recipes on each type of tool. Running different recipes (having different process times) on individual tools increases process time variability. And as we have discussed many times in the newsletter, increasing process time variability directly (and non-linearly) increases operation cycle times. The greater the number of different products in the fab, the more different recipes there are with potentially different process times. This is particularly true for certain types of tools.

Setups. Having many different products can lead to extra setups on certain tools. Setups take away standby time on these tools, and hence drive up utilization (where utilization is defined as Productive Time / [Productive + Standby Time]). And, as we have again discussed many times, increasing utilization on a tool (by reducing the amount of standby time) increases cycle time.

Batching. Having many different products, with different recipes, makes it harder to form batches at batch tools. Lots may wait longer to be put into a batch, especially for lower volume recipes, driving up cycle time. It may also be necessary to run smaller batches, resulting in lost capacity on the batch tools.

Dispatching. In general, dispatching (deciding which lot to process next on each tool) is more challenging the more different products you have. Dispatch rules may need to include relative priorities of the different products, for example. They may also need to be amended to ensure that low-volume products don't sit in queue indefinitely. Dispatch rules also need to be kept somewhat flexible in a high mix environment, since priorities are likely to change rapidly.

Reticle Management. The more recipes you have, the more of an issue managing reticles becomes. This can lead to extra queueing for lots, as they wait for the correct reticle to be located and brought to the proper tool.

All of these things are management issues in most fabs. However, the greater the degree of mix in the fab, the more likely they are to become problems.

High Mix: Short Product Life Cycles

Even if you don't have a huge volume of products or technologies, running a fab in which the product life cycles are very short also leads to cycle time challenges. These include:

Unbalanced Tool Utilizations. The rapid introduction of new products can lead to unbalanced tool utilizations across different tool groups. For instance, you might have certain metal layers assigned to certain subsets of tool groups. The introduction of a new product could increase the loading on one of these sub-groups, while decreasing the loading on another. Because cycle time increases non-linearly with utilization, the sub-group with higher loading may have significantly higher cycle time (especially if the tool is less than reliable). This tends to drive up cycle time. Obviously, layers can be reassigned to tools in light of product mix changes. However, if the mix changes happen very rapidly, or very frequently, this is difficult to maintain.

Learning Curves. Changes in products, and the introduction of new products, require learning curves for both manufacturing and engineering (productivity learning and yield learning). Yield improvement activities during the yield ramp can themselves add variability, especially when they take away tools from production.

Holds. New products are likely to be placed on hold more frequently than well-established products, and to stay on hold for longer periods of time. This hold time inflates shipped lot cycle times. We discussed holds in detail in Issue 6.06.

Benchmarking/Goal Setting. In a fab with short product life cycles, and hence relatively low volumes of each product run during the same time period, benchmarking results and setting cycle time goals can be difficult. There simply isn't enough data sometimes to draw conclusions about what is a reasonable cycle time to expect (especially in the presence of learning cycles). This makes it hard to set goals for improvement.

So What? I Can't Change the Product Mix in the Fab

It's all very well to outline potential interactions between cycle time and product mix. However, in most fabs, simply cutting down the amount of product mix isn't an option (especially during major fab transitions, such as a wafer size change). It's not an option for the people who work on the floor, at any rate. What you can do, however, if you are in a high mix environment, is look to the issues cited above for improvement opportunities. A few specific ideas are listed below.

Notification of Single-Path Operations: It's a good idea in any fab to have a regular report that highlights any WIP that is waiting at a single-path operation. This is especially helpful in cases where product mix leads to frequent shifts in tool

dedication strategies. We have seen fabs where any change that is going to result in single-path operations requires an extra approval cycle. We think, where feasible, that this is a good idea.

Early Warning of Utilization Increases: If product mix changes lead to unbalanced tool groups in your fab, you could set up some type of early warning alert. If a toolgroup starts having actual utilization values significantly higher than planned, this would warn you to reassign tools from another sub-group, until the situation stabilizes. A system like this may also help by notifying you about "soft dedication" issues, when your process engineers haven't necessarily made a change, but the operators on the floor are using tools unevenly.

Use of Product Families for Measuring Performance Data: For goal setting and benchmarking, we recommend identifying families of like products, and using that more broad data to overcome shortfalls in the historical data for each individual product. In FabTime's software, for example, you can slice metrics by Family, Technology, Product, and Route, depending on the required level of granularity.

Reticle Management Systems: You might consider computer-based reticle management systems, in light of the potential for cycle time improvement. Does your reporting system let you break out tool unavailable time (or lot queue time) in enough detail to let you see time spent waiting for reticles?

Hold Reduction Programs: If you find that holds are a significant contributor to cycle time, you may benefit from an analysis of the reasons for holds, and/or a warning system to alert you before long hold times accumulate.

Setup Reduction Programs: The higher the degree of product mix in your fab, the more benefit you stand to gain from setup reduction programs. It's also particularly important in a high-mix environment to have limits on how long you allow lots to wait in queue before forcing a setup. This is because, under a setup-avoidance policy at a high-utilization tool, low volume lots can sometimes sit for a very long time. This was discussed in more detail in Issue 6.07.

Process Simplification: High-mix environments are also a good argument for process simplification. It's not as much of an issue to introduce new products if your flows are relatively modular, such that the new products aren't significantly different from the older ones. This tends to help with batching issues, in particular, where you can allow different product types to be batched together at certain common operations.

Conclusions

If you work in a fab that runs many different products, and/or encounters frequent changes in product mix, you probably know instinctively that you could improve cycle time if you could somehow ratchet down the level of product mix. Unfortunately, in the presence of today's ever-increasing market differentiation and ever-shrinking consumer product life cycles, a reduction in product mix is not very likely to occur. Instead, we're likely to see an increasing proliferation of products, introduced more and more rapidly.

In this article we have analyzed several of the fundamental reasons why increasing product mix may increase cycle time. These include: increased process time variability; more setups; longer waits to form batches; more complex reticle management and dispatching; unbalanced tool utilization for smaller tool groups; learning curves for productivity and yield; and difficulty in setting goals from historical data. These suggest particular areas of focus for high mix fabs, to attempt to counteract these problems. Examples might include setup reduction initiatives and early warning indicators for tool

groups that have higher than expected utilization.

Looking back at the original question that motivated re-consideration of the issue of product mix, we wouldn't go so far as to say that increasing cycle time is inevitable in the wake of increasing the technology mix of an existing fab. However, we will say that if you add technology mix to an existing fab, and you don't make some sort of adaptation to account for that increased mix, then cycle time is very likely to increase. We hope that this article has left you with some ideas for those adaptations.

Closing Questions for FabTime Subscribers

Do you think that increased cycle time is inevitable in the face of increased technology mix? If not, what have you done to mitigate the effect of technology mix on cycle time? Are there other issues stemming from product/process mix that we're missing in this article?

Further Reading

C.-S. Bong and K. V. Karuppiah, "Cycle-Time Reduction Under Product Diversity in Semiconductor Back-End Manufacturing," *Proceedings of the International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM 2002)*, Editors G. T. Mackulak, J. W. Fowler, and A. Schoemig, Tempe, AZ, April 10-12, 2002. 260-263.

Yon-Chun Chou; L-Hsuan Hong, "A Methodology for Product Mix Planning in Semiconductor Foundry Manufacturing," *IEEE Transactions on Semiconductor Manufacturing*, Vol. 13, No. 3, 278-285, 2000.

Shu-Hsing Chung, Amy H. I. Lee, and W. L. Pearn, "Product Mix Optimization for Semiconductor Manufacturing Based on AHP and ANP Analysis," International *Journal of Advanced Manufacturing Technology*, Vol. 25, No. 11-12, 1144-1156, 2005.

M. A. Dümmler, "Analysis of the Instationary Behavior of a Wafer Fab during Product Mix Changes," *Proceedings of the 2000 Winter Simulation Conference*, 2000. (All WSC papers since 1997 are available for free download from http://www.informs-cs.org/wscpapers.html).

Kamil Erkan Kabak and Cathal Heavey (University of Limerick) and Vincent Corbett (Analog Devices), "Analysis of Multiple Process Flows in an ASIC Fab with a Detailed Photolithography Area Model", *Proceedings of the 2008 Winter Simulation Conference*, Miami, FL, December 7-10, 2008.

Moti Klein and Adar Kalir (Intel), "A Full Factory Transient Simulation Model for the Analysis of Expected Performance in a Transition Period," *Proceedings of the 2006 Winter Simulation Conference*, Monterey, CA, December 3-6, 2006.

T. Miwa, "Automated Stepper Load Balance Allocation System Using On-line Subsequent Layer Processing Time Estimation," *Proceedings of the 2004 International Symposium on Semiconductor Manufacturing (ISSM 2004)*, Tokyo, Japan, 2004. This paper describes an automated stepper load balance allocation system developed to improve productivity in the photolithography process of high-product-mix/low-volume factories by balancing load distribution of tool constraint layers across steppers.

A. M. Murray and D. J. Miller, "Automated Reticle Handling: A Comparison of Distributed and Centralized Reticle Storage and Transport," *Proceedings of the 2003 Winter Simulation Conference*, S. Chick, P. J. Sánchez, D. Ferrin, and D. J. Morrice, eds., 2003.

Subscriber List

Total number of subscribers: 2747 from 464 companies and universities.

Top 20 subscribing companies:

- Maxim Integrated Products, Inc. (185)
- Intel Corporation (147)
- Chartered Semiconductor Mfg (87)
- Micron Technology, Inc. (79)
- Western Digital Corporation (76)
- X-FAB Inc. (69)
- Texas Instruments (63)
- TECH Semiconductor Singapore (60)
- ON Semiconductor (58)
- Freescale Semiconductor (56)
- Analog Devices (54)
- NEC Electronics (50)
- International Rectifier (49)
- IBM (46)
- STMicroelectronics (46)
- Infineon Technologies (46)
- GLOBALFOUNDRIES (40)
- Seagate Technology (39)
- Cypress Semiconductor (38)
- ATMEL (33)

Top 3 subscribing universities:

- Virginia Tech (11)
- Arizona State University (8)
- Ben Gurion Univ. of the Negev (8)

New companies and universities this month:

- Fujifilm Dimatix
- Intermolecular
- KSK Surya
- Solexel
- Solexant
- THAT Corporation

Note: Inclusion in the subscriber profile for this newsletter indicates an interest, on the part of individual subscribers, in cycle time management. It does not imply any endorsement of FabTime or its products by any individual or his or her company.

There is no charge to subscribe and receive the current issue of the newsletter each month. Past issues of the newsletter are currently only available to customers of FabTime's web-based digital dashboard software or cycle time management course.

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FabTime® Cycle Time Management Training

"It was helpful to see best-in-class methods for wafer fab cycle time management. Discussing these matters in-depth with you was quite valuable, as we could ask questions specific to our fab and processes."

Shinya Morishita
Manager, Wafer Engineering
TDK Corporation

Course Code: FT105

This course provides production personnel with the tools needed to manage cycle times. It covers:

- Cycle time relationships
- Metrics and goals
- Cycle time intuition

Price

$7500 plus travel expenses for delivery at your site for up to 20 participants, each additional participant $300. Discounts are available for multiple sessions.

Interested?

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Do you make the best possible decisions?

- Do your supervisors possess good cycle time intuition?
- Are you using metrics that identify cycle time problems early?
- Can you make operational changes to improve cycle time?

FabTime's Cycle Time Management Training is a one-day course designed to provide production personnel with an in-depth understanding of the issues that cause cycle time problems in a fab, and to suggest approaches for improving cycle times. A two-day version is also available upon request.

Prerequisites

Basic Excel skills for samples and exercises.

Who Can Benefit

This course is designed for production personnel such as production managers, module managers, shift supervisors, hot lot coordinators, and production control.

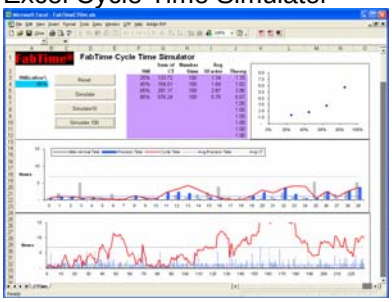
Skills Gained

Upon completion of this course, you will be able to:

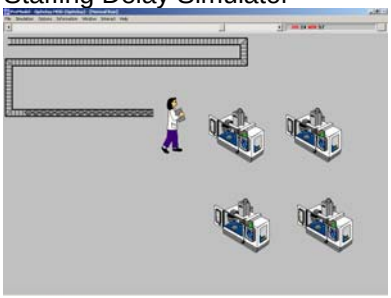
- Identify appropriate cycle time management styles.
- Teach others about utilization and cycle time relationships.
- Define and calculate relevant metrics for cycle time.
- Teach others about Little's law and variability.
- Quantify the impact of single-path tools and hot lots.
- Apply cycle time intuition to operational decisions.

Sample Course Tools

Excel Cycle Time Simulator



Staffing Delay Simulator



Additional Half-Day Modules

- Executive Management Session.
- Site-Specific Metrics Review.
- Capacity Planning Review and Benchmark.